Registration of 'RWA 1758' Russian Wheat Aphid-Resistant Spring Barley

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ABSTRACT

'RWA 1758' (Reg. No. CV-336; PI 648913) is a spring, Russian wheat aphid (*Diuraphis noxia* Mordvilko) (RWA)–resistant two-rowed barley (*Hordeum vulgare* L.) developed by the USDA-ARS. RWA 1758 was selected and released on the basis of competitive agronomic performance and resistance to damage caused by RWA feeding. RWA 1758 derives from a $BC_3F_{3:4}$ selection from the cross 'Baronesse'*4/STARS 9577B. It was tested under the experimental designation 01ST1758. STARS 9577B is a six-rowed spring RWA-resistant germplasm line developed and released by the USDA-ARS. STARS 9577B is resistant to the five RWA biotypes known to be present in the United States. STARS 9577B was developed via selection from CIho 4165, a landrace originally collected in Afghanistan. The main component of the resistance is tolerance, conferred by two dominant genes with recessive epistasis.

'RWA 1758' (Reg. No. CV-336; PI 648913) is a Russian wheat aphid (*Diuraphis noxia* Mordvilko) (RWA)–resistant, spring, two-rowed barley (*Hordeum vulgare* L.) tested under the experimental designation 01ST1758 that was developed and released by the USDA-ARS. RWA 1758 was selected primarily for its resistance to RWA feeding damage. It derives its RWA resistance from STARS 9577B (Mornhinweg et al., 1999), which was selected from CIho 4165, a landrace collected in Afghanistan. This source of resistance is distinct from the resistance in 'Burton' (Bregitzer et al., 2005). Burton's resistance comes from STARS 9301B (Mornhinweg et al., 1995), which was selected from PI 366450, a landrace also collected in Afghanistan. Resistance in STARS 9577B is conferred by two dominant genes with recessive epistasis, while resistance in STARS 9301B is conferred by one incompletely dominant and one dominant gene with epistasis (Mornhinweg et al., 1999). The major component of resistance to RWA feeding damage in both STARS 9301B and in STARS 9577B is tolerance.

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Abbreviations: WRDSBN, Western Regional Dryland Spring Barley Nursery; WRSBN, Western Regional Spring Barley Nursery.

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RWA 1758 was also selected on the basis of high grain yields and test weight, as well as resistance to lodging. RWA 1758 is expected to be widely adapted to irrigated and rainfed conditions characteristic of the Intermountain western region of the United States (Colorado, Idaho, Montana, Washington, and Oregon). It is not believed to possess the necessary levels of resistance to foliar leaf diseases that are critical for commercial success in the upper Midwest.

RWA 1758 has the pedigree 'Baronesse'*4/STARS 9577B. Baronesse is a two-rowed feed barley that is well adapted to irrigated and rainfed production areas in the western United States. It was developed by Nordsaat in Germany and is marketed in the United States by WestBred, LLC (Bozeman, MT).

Methods

RWA 1758 was developed using a modified backcross breeding procedure. The initial cross was made and advanced to the BC_3F_3 generation in a greenhouse in Stillwater, OK. Selection for RWA resistance was as described (Webster et al., 1991). Briefly, seedlings were infested at emergence with RWAs and scored for RWA damage after 3 wk. Russian wheat aphid damage was scored using Webster's scale (Webster et al., 1991), where reactions scored 1 to 3 are considered resistant, 4 to 6 are considered moderately resistant, and 7 to 9 are considered susceptible. Susceptible seedling reactions are characterized by the development of chlorotic leaves, emerging leaves remain tightly rolled and develop chlorotic strips, and generally the seedlings die before scoring. In contrast, infestation of STARS 9577B seedlings results in minimal chlorosis, no streaking or rolling of emerging leaves, and a rating of 3 on Webster's scale.

Following the initial cross, each backcross population was produced by crossing approximately five BC_xF_1 plants to the recurrent parent, Baronesse, and bulking the resulting $BC_{x+1}F_1$ seed, resulting in populations consisting of approximately 70 to

100 individuals that were used for further population development. Starting with the BC_1F_1 population, the resistant progeny used for the next cycle of backcrossing were identified on the basis of seedling resistance to RWA infestation. This process was repeated through BC_3. Multiple (approximately 12) resistant BC_3F_1 progeny were self-pollinated to produce a bulk BC_3F_2 population, which was again screened for resistance. Resistant BC_3F_2 plants were harvested and progeny tested to identify lines that were homozygous for RWA resistance. In some cases, an additional generation of seed increase was conducted to provide sufficient seed for further testing. Remnant seed from 123 $BC_3F_{2:3}$ or $BC_3F_{2:4}$ lines from putatively homozygous BC_3F_2 plants were planted in 1.3-m-long progeny rows in an irrigated nursery at Aberdeen, ID, in 2001. From visual observations, 18 progeny rows that exhibited vigorous growth, favorable maturity characteristics, resistance to lodging, and plump kernels were selected for further testing. Selected rows were again subjected to seedling assays for resistance to RWA as described above. Homozygosity for resistance to RWA damage was confirmed for 16 of the 18 lines, which were advanced to replicated small-plot yield trials.

RWA 1758 was entered in preliminary yield trials in 2002 at two Idaho locations: Aberdeen (sprinkler irrigated, elevation 1338 m) and Tetonia (rainfed, elevation 1794 m). The experimental design was a randomized complete block with two replicates. Six lines were selected for further testing on the basis of plant characteristics (height, maturity, and resistance to lodging) and productivity characteristics (grain yield, test weight, kernel plumpness). From 2003 through 2006, testing was expanded to include additional sites in Idaho that varied with respect to elevation, sowing and harvest dates, and water availability: Ashton, 2005–2006 (rainfed, elevation 1698 m); Filer, 2003–2006 (furrow irrigated, elevation 1064 m); Idaho Falls, 2005–2006 (sprinkler irrigated, elevation 1422 m); Potlatch, 2005 (rainfed, elevation 790 m); Rupert, 2005–2006 (sprinkler irrigated, elevation 1277 m); Soda Springs, 2003–2006 (rainfed, elevation 1762 m); and Tammany, 2005 (rainfed, elevation 430 m). These sites provided a wide range of conditions, and the highest average nursery yield was typically double that of the lowest nursery average yield. The primary sources of stress were abiotic (temperatures >30°C and/or limited moisture). Disease and insect problems were negligible. The experimental design at each location was a randomized complete block with either three or four replicates. Soil fertility was managed according to soil test results and recommendations for yield goals appropriate for the site based on site characteristics, including considerations of production histories, anticipated water availability, and avoidance of excessive lodging. All plots were sown with small-plot drills equipped with double-disc openers. Each plot consisted of seven rows on 17.8-cm centers, and—depending on the location and year tested—varied from approximately 2.4 to approximately 3 m in length. Plot arrangement was such that the experiments consisted of ranges of 7 to 20 side-by-side plots. Each range was separated by an alley approximately 1 m in width. Harvest was accomplished by small-plot combines.

RWA 1758 was tested by cooperators at Center, CO (irrigated, 2005–2006), Yellow Jacket, CO (rainfed, 2004 and 2006), and Sidney, NE (irrigated and rainfed 2005), using methods similar to those described above. In the Yellow Jacket and Sidney trials, natural RWA infestations occurred. These trials included Baronesse treated with Gaucho insecticide (a.i. imidicloprid; Bayer Crop Sciences, Research Triangle Park, NC) as directed by the manufacturer. Comparison of treated vs. untreated Baronesse performance provided an indication of RWA damage. RWA 1758 was tested also in the Western Regional Spring Barley Nursery (WRSBN) and in the Western Regional Dryland Spring Barley Nursery (WRDSBN) during 2005 and 2006 (details regarding these tests are found in Erickson 2006, 2007).

Data collected during the testing of RWA 1758 included days to heading (date of head emergence from the boot for 50% of plants; visual estimate), plant height, percentage of lodged plants (visual estimate), grain yield, test weight, and percentage plump kernels (defined as the percentage of kernels retained on a sieve with 19.1- × 2.38-mm rectangular openings, Method Barley 2C: Assortment test, American Society of Brewing Chemists, 1992). Data were analyzed by SAS v. 8.0 Proc GLM (1999, SAS Institute Inc., Cary, NC), utilizing the PROC GLM procedure, using various statistical models. Typical models included cultivar, locations, and years as sources of variance, with all sources of variance considered random except for cultivar. *F* tests were considered significant at $p < 0.05$.

RWA 1758 was observed to be uniform in appearance from the F_4 through the F_8 generation. Breeder's seed was produced by bulking approximately 348 $F_{7:8}$ rows that were uniform and indistinguishable from each other in appearance, and which were shown to be uniform for seedling resistance to RWA feeding damage. Resistance was determined by assays (as described above) of 30 seedlings per row, conducted after the rows were harvested.

Characteristics

RWA 1758 is a hulled, RWA-resistant, spring, two-rowed barley. It has an erect juvenile growth habit. Adult plants are medium-tall. Stems have five nodes, a *v*-shaped collar, moderate spike exertion, and a strap-shaped, semilax spike that nods at maturity. Lemma awns are long and rough. Glume awns are rough, and glume hairs are banded. Rachilla hairs are long. Rachis edges are covered with hairs. Hulls have prominent, barbless, lateral veins, and a depression at the base. Aleurone is white.

The source of the RWA resistance is STARS 9577B (Mornhinweg et al., 1999), which was selected from CIho 4165, a six-rowed landrace originally collected in Afghanistan. Although the primary mechanism of resistance to RWA feeding damage is tolerance, antibiosis also occurs (Mornhinweg et al., 1999). In field environments, resistant lines have been observed to support smaller RWA populations than susceptible lines (Bregitzer et al., 2003). However, in protected greenhouse environments, large populations develop on both resistant and susceptible lines, and thus, reduced RWA populations on resistant lines may be the result of increased exposure to wind, rain, and predators caused by the lack of leaf rolling (Mornhinweg, unpublished data). Genetic analysis indicated that the resistance is controlled by two dominant genes with recessive epistasis (Mornhinweg et al., 1999, 2002). Although five RWA biotypes have been reported in wheat (*Triticum aestivum* L.) (Burd et al., 2006; Haley et al., 2004), RWA 1758 has shown no differential susceptibility to these five biotypes (Puterka et al., 2006) or any other suspected biotypes identified to date (Mornhinweg, unpublished data).

Replicated tests for agronomic characteristics have been conducted in multiple irrigated and rainfed environments in Idaho, Colorado, Nebraska, and in the 2005 and 2006 WRSBN and WRDSBN. The data indicate that RWA 1758 has favorable characteristics for yield, test weight, maturity, plant height, and resistance to lodging. Tests conducted at nine Idaho locations from 2003 through 2006 (22 location-years) showed that RWA 1758 was competitive with its recurrent parent, Baronesse, and with the RWA-resistant cultivar Burton (Table 1). RWA 1758 was shorter than Baronesse and Burton, had higher grain yield than Burton, and had a lower percentage of plump kernels than Burton (Table 1). Tests conducted at Center, CO, during 2005 and 2006 also showed RWA 1758 to be competitive for agronomic performance, including with 'Eslick' which was the top-yielding cultivar in both years (Table 2). Data from the regional trials conducted in 2005 and 2006 are shown in Table 3; details on statistical comparisons are available as specified in the "Methods" section. RWA 1758 did not show significant differences from Baronesse except that it was significantly shorter ($p < 0.05$) in the 2006 WRSBN.

All of the data presented above were collected in trials where RWA infestations were absent or negligible. Natural RWA infestations occurred in trials conducted at Yellow Jacket, CO (rainfed, 2004 and 2006), and at Sidney, NE (rainfed and irrigated, 2005). Significant yield reductions were observed at Yellow Jacket trials (Table 4) and in the rainfed Sidney trial (Table 5) for untreated vs. Gaucho insecticide–treated untreated checks, but not in the irrigated Sidney trial (Table 6). The greatest yield reduction from RWA feeding was seen in the rainfed Sidney trial, where untreated Baronesse yielded 71% of that recorded for Gaucho-treated Baronesse. In this trial, RWA 1758 had higher yield than untreated Baronesse and did not differ significantly from Gaucho-treated Baronesse or Burton except that it showed, respectively, lower and higher test weight. At Yellow Jacket, RWA 1758 did not differ significantly from Gaucho-treated Baronesse or Burton except that RWA 1758 was shorter than Burton. The higher yield of RWA 1758 vs. untreated Baronesse was not significant at $p = 0.05$.

Table 1. Agronomic performance of RWA 1758, Baronesse, and Burton at nine Idaho locations from 2003 through 2006 (22 location-years).

Cultivar	RWA resistance†	Heading	Height	Lodging	Yield	Test wt.	Plump kernels‡
		d from 1 Jan.	cm	%	kg ha^{-1}	kg m^{-3}	%
Baronesse	susceptible	180	75	19	5398	665	80
RWA 1758	resistant	180	71	18	5394	672	81
Burton	resistant	180	78	12	5059	670	85
	LSD $p = 0.05$	ns	3	ns	263	ns	4

†RWA, Russian wheat aphid.

‡Defined as the percentage of kernels retained on a sieve with 19.1- × 2.38-mm rectangular openings, Method Barley 2C: Assortment test (American Society of Brewing Chemists, 1992).

Table 2. Agronomic performance of RWA 1758 and selected checks under irrigation at Center, CO, 2005 and 2006.

Cultivar	RWA resistance†	Heading	Height	Lodging	Yield	Test wt.
		d from 1 Jan.	cm	%	kg ha^{-1}	kg m^{-3}
Eslick	susceptible	174	85	8	8573	672
RWA 1758	resistant	175	79	1	8331	672
Comarque	susceptible	179	74	0	7982	683
Haxby	susceptible	173	90	1	7525	674
Burton	resistant	179	86	0	7256	669
Harrington	susceptible	178	90	8	6934	672
Robust	susceptible	171	103	2	6746	664
	LSD $p = 0.05$	1	5	10	586	12

†RWA, Russian wheat aphid.

Table 3. Performance of RWA 1758 and Baronesse in the Western Regional Spring Barley Nurseries (WRSBN) and the Western Regional Dryland Spring Barley Nurseries (WRDSBN), 2005–2006.

Cultivar	Heading	Height	Yield	Test wt.	Plump kernels†
	d from 1 Jan.	cm	kg ha^{-1}	kg m^{-3}	%
WRSBN					
Baronesse	181	77/80‡	6010	673	88
RWA 1758	180	75/67‡	5952	678	90
lsd $p = 0.05$	ns	ns/3‡	ns	ns	ns
location-years	19	10/11‡	26	23	20
WRDSBN					
Baronesse	184	64	4201	646	80
RWA 1758	183	64	4182	653	81
LSD $p = 0.05$	ns	ns	ns	ns	ns
location-years	15	13	18	16	14

†Defined as the percentage of kernels retained on a sieve with 19.1- × 2.38-mm rectangular openings, Method Barley 2C: Assortment test (American Society of Brewing Chemists, 1992).

‡Genotype by environment interaction existed; data are presented separately: 2005/2006.

Table 4. Agronomic performance of RWA 1758, Baronesse, and Burton at Yellow Jacket, CO, 2004 and 2006.

Cultivar	RWA resistance†	Heading	Height	Lodging	Yield	Test wt.	Plump kernels‡	RWAs per 20 tillers§
		d from 1 Jan.	cm	%	kg ha^{-1}	kg m^{-3}	%	
Baronesse + G¶	susceptible	192	72	33	6676	648	93	0
RWA 1758	resistant	189	68	8	6468	646	95	4
Burton	resistant	192	82	4	6462	648	97	0
Baronesse	susceptible	192	70	50	5924	654	95	3
	LSD $p = 0.05$	2	4	ns	602	ns	ns	

†RWA, Russian wheat aphid.

‡Defined as the percentage of kernels retained on a sieve with 19.1- × 2.38-mm rectangular openings, Method Barley 2C: Assortment test (American Society of Brewing Chemists, 1992).

§Counts of RWAs made at heading; data from 2004 only.

¶Treated with Gaucho insecticide.

Table 5. Agronomic performance of RWA 1758 and selected checks under rainfed conditions at Sidney, NE, 2005.

Cultivar	RWA resistance†	Heading	Height	Lodging	Yield	Test wt.	Plump kernels‡	RWAs per 20 tillers§
		d from 1 Jan.	cm	%	kg ha^{-1}	kg m^{-3}	%	
Baronesse + G¶	susceptible	169	76	15	4222	604	48	44
RWA 1758	resistant	171	74	5	3830	588	56	44
Burton	resistant	173	79	10	3695	579	56	42
Stoneham#	resistant	165	81	88	3135	578	60	70
Baronesse	susceptible	171	74	3	3012	587	42	330
Otis + G¶	susceptible	172	69	80	2598	556	31	98
Otis	susceptible	172	71	63	2228	541	29	150
Sidney#	resistant	171	76	65	2195	568	60	60
Conlon	susceptible	169	79	10	1937	553	56	226
	LSD $p = 0.05$	2	7	16	430	9	nd††	

†RWA, Russian wheat aphid.

‡Defined as the percentage of kernels retained on a sieve with 19.1- × 2.38-mm rectangular openings, Method Barley 2C: Assortment test (American Society of Brewing Chemists, 1992).

§Counts of RWAs made at heading.

¶Treated with Gaucho insecticide.

#RWA-resistant cultivars developed via backcrosses to Otis: Stoneham = Otis*4/STARS 9577B; Sidney = Otis*4/STARS 9301B.

††nd = not determined; plumps determined from a single composite sample from all replicates.

Table 6. Agronomic performance of RWA 1758 and selected checks under irrigation at Sidney, NE, 2005.

Cultivar	RWA resistance†	Heading	Height	Lodging	Yield	Test wt.	Plump kernels‡
		d from 1 Jan.	cm	%	kg ha^{-1}	kg m^{-3}	%
Baronesse + G§	susceptible	171	81	38	4681	605	36
Drummond	susceptible	169	89	40	4513	592	30
Burton	resistant	171	89	40	4468	587	39
Lacey	susceptible	170	81	25	4356	593	40
Baronesse	susceptible	171	81	40	4356	596	32
RWA 1758	resistant	171	81	63	4322	598	31
Conlon	susceptible	167	89	30	4210	600	60
Robust	susceptible	168	94	58	4042	575	36
Harrington	susceptible	173	76	8	3774	583	46
	LSD $p = 0.05$	2	8	37	645	24	nd¶

†RWA, Russian wheat aphid.

‡Defined as the percentage of kernels retained on a sieve with 19.1- × 2.38-mm rectangular openings, Method Barley 2C: Assortment test (American Society of Brewing Chemists, 1992).

§Treated with Gaucho insecticide.

¶nd = not determined; plumps determined from a single composite sample from all replicates.

In the irrigated Sidney trial, RWA 1758 was not significantly different from either treated or untreated Baronesse or Burton except that it was shorter than Burton.

RWA 1758 has been tested primarily under conditions that are not conducive to disease, and little is known about its resistance to common barley diseases. RWA 1758 is not expected to be well adapted to environments characterized by high disease pressure.

Availability

U.S Plant Variety Protection for RWA 1758 has been granted (PVP no. 200700405). Small quantities of seed to be used for research or breeding purposes can be requested from the corresponding author during the period of protection by the Plant Variety Protection Certificate. Parties interested in commercial production of RWA 1758 may also contact the corresponding author for details on obtaining seed. Seed of this release is deposited in the National Plant Germplasm System, where it will be available after the expiration of the Plant Variety Protection (20 yr from date of PVP issuance) without restriction. It is requested that appropriate recognition be made when this cultivar contributes to research or development of new breeding lines or cultivars.

References

American Society of Brewing Chemists. 1992. Methods of analysis. 8th ed. American Society of Brewing Chemists, St Paul, MN.

Bregitzer, P., D.W. Mornhinweg, and B.L. Jones. 2003. Resistance to Russian wheat aphid damage derived from STARS 9301B protects agronomic performance and malting quality when transferred to adapted barley germplasm. Crop Sci. 43:2050–2057.

Bregitzer, P., D.W. Mornhinweg, R. Hammon, M. Stack, D.D. Baltensperger, G.L. Hein, M.K. O'Neill, J.C. Whitmore, and D.J. Fiedler. 2005. Registration of 'Burton' barley. Crop Sci. 45:1166–1167.

Burd, J.D., D.R. Porter, G.J. Puterka, S.D. Haley, and F.B. Peairs. 2006. Biotypic variation among north American Russian wheat aphid (Homoptera: Aphididae) populations. J. Econ. Entomol. 99:1862–1866.

Erickson, C.A. 2006. 2005: The western regional spring barley nursery and the western regional dryland spring barley nursery. Available at http://www.ars.usda.gov/SP2UserFiles/Place/53660000/2005WRBNREPORT.pdf (verified 30 Nov. 2007). USDA-ARS, Northern Plains and Pacific West Regions, Aberdeen, ID.

Erickson, C.A. 2007. 2006: The western regional spring barley nursery and the western regional dryland spring barley nursery. Available at http://www.ars.usda.gov/SP2UserFiles/Place/53660000/2006WRBNREPORT.pdf (verified 30 Nov. 2007). USDA-ARS, Northern Plains and Pacific West Regions, Aberdeen, ID.

Haley, S.D., F.B. Peairs, C.B. Walker, J.B. Rudolph, and T.L. Randolph. 2004. Occurrence of a new Russian wheat aphid biotype in Colorado. Crop Sci. 44:1589–1592.

Mornhinweg, D.W., D.R. Porter, and J.A. Webster. 1995. Registration of STARS-9301B barley germplasm resistant to Russian wheat aphid. Crop Sci. 35:603.

Mornhinweg, D.W., D.R. Porter, and J.A. Webster. 1999. Registration of STARS-9577B Russian wheat aphid resistant barley germplasm. Crop Sci. 39:882–883.

Mornhinweg, D.W., D.R. Porter, and J.A. Webster. 2002. Inheritance of Russian wheat aphid resistance in spring barley germplasm line STARS-9577B. Crop Sci. 42:1891–1893.

Puterka, G.J., J.D. Burd, D.W. Mornhinweg, S.D. Haley, and F.B. Peairs. 2006. Response of resistant and susceptible barley to infestations of five Diuraphis noxia (Homoptera: Aphididae) biotypes. J. Econ. Entomol. 99:2151–2155.

Webster, J.A., C.A. Baker, and D.R. Porter. 1991. Detection and mechanisms of Russian wheat aphid (Homoptera: Aphididae) resistance in barley. J. Econ. Entomol. 84:669–673.